BEFORE THE TASMAN DISTRICT COUNCIL

Under	the Resource Management Act 1991
In the matter of	an application by **THE NELSON REGIONAL SEWERAGE BUSINESS UNIT** for the resource consents to continue applying biosolids to land on Moturoa/Rabbit Island.

STATEMENT OF EVIDENCE OF JIANMING XUE FOR THE NELSON REGIONAL SEWERAGE BUSINESS UNIT

11TH MAY 2022

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STATEMENT OF EVIDENCE OF JIANMING XUE

Introduction

1 My full name is Jianming Xue. I have a PhD degree in Forestry (UC, NZ), a MPhil in Environmental Soil Science (UW, NZ), a MSc in Plant Nutrition (ZU, China) and a BSc in Soil Science (ZU, China). I am a Senior Scientist at Scion and the Science Leader of Soil and Plant Group at the Centre for Integrated Biowaste Research in New Zealand.

2 I have 40 years' experience in soil science and plant nutrition. My areas of expertise are integrated soil fertility and nutrient management, genetic and environmental control of resource use efficiency, the fate and transport of nutrient and contaminants in ecosystems, and reuse and land application of biowastes. My current research focusses on developing sustainable biowaste reuse solutions for improving soil quality and forest productivity with minimal environmental and ecological footprints. Scion established a long-term biosolids research trial at Rabbit Island since 1997 and I have been doing research on the impact of biosolids application on tree growth and soil quality based on this long-term research trial since 2011.

3 I am involved in this project as an expert in tree nutrition and soil fertility. I have provided an independent technical report titled as "Assessing the impact of land application of biosolids on planted pine forest and soil properties at Moturoa / Rabbit Island" (the **Tree Nutrition and Soil Fertility Report** / **TNSF Report**).

4 While this is a Council-level hearing, I acknowledge that I have read and am familiar with the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2014, and that I agree to comply with it. I confirm that this evidence is within my area of expertise, except where I state that this evidence is given in reliance on another person's evidence. I have considered all material facts that are known to me that might alter or detract from the opinions I express in this evidence.

Scope of Evidence

5 In my evidence I will outline the following:

5.1 An overview of the existing land application of biosolids at Rabbit Island

5.2 Beneficial use of biosolids as a fertiliser to improve tree growth and nutrition

5.3 Beneficial use of biosolids as a soil amendment to enhance soil fertility and quality

5.4 Potential risks of land application of biosolids

5.5 Updates since submission of AEE

5.6 Summary of findings

5.7 Guidance to biosolid application

5.8 Resource Consent Conditions

5.9 Comments on Officer's Report

5.10 Comments on submissions where relevant to my evidence

Land application of biosolids at Rabbit Island

6 The use of biosolids as a fertiliser and soil amendment for improvement of low fertility soils and reclamation of degraded land is a common biosolids management option in many parts of the world [1-3]. In New Zealand, application of biosolids on forest land is the preferred option, rather than application on agricultural land. This is because it can reduce the potential for contaminants to enter the human food chain, and can also increase tree growth and subsequent economic returns [3-5].

7 Treated biosolids (Class A as defined by Biosolids Guidelines [6]) from the Bell Island wastewater treatment plant have been applied to radiata pine forest in the operational areas at Moturoa / Rabbit Island in Nelson since 1996, at the rates of 300 or 450 kg N ha^{-1} every 3 years depending on the stand age (Fig 1) [7].

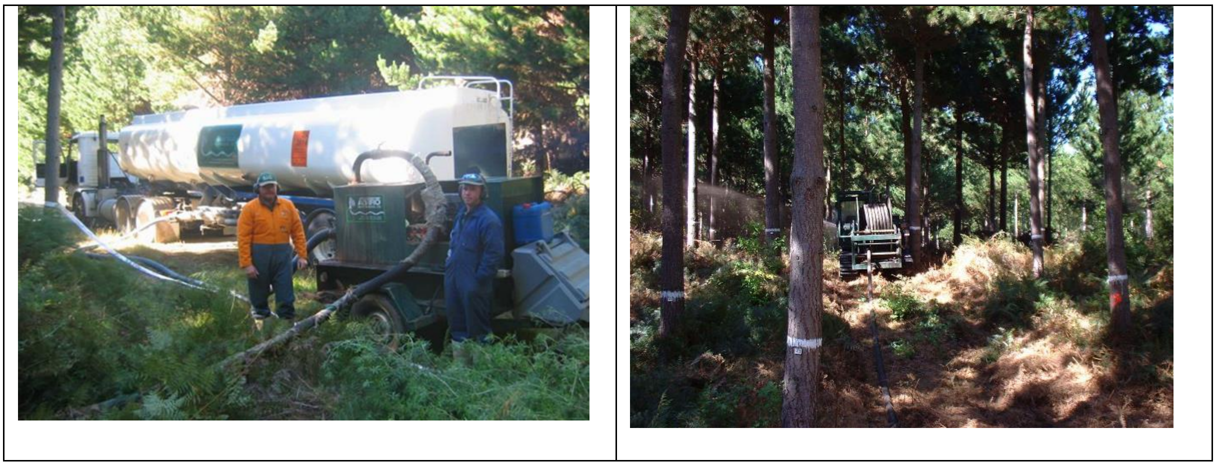

Fig.1 Land application of biosolids in a pine forest at Rabbit Island in Nelson

8 To investigate the long-term effects of biosolids application on soil quality, groundwater quality, tree nutrition, and tree growth, a long-term biosolids research trial was established at Moturoa/ Rabbit Island in 1997 [3-5,7-9]. The Nelson Regional Sewerage Business Unit (**NRSBU**) commissioned Scion to conduct this trial (the **research trial)** which, alongside an assessment and comparison of the soil quality within operational forest areas outside of the research trial site, made up the detail of the TNSF Report.

9 The data and conclusions underpinning this Statement of Evidence were derived predominantly from the research trial, but the purpose of this evidence is to highlight the key outcomes and

conclusions relied on our original assessment report [10] and provide insights and comparisons on the updated operational data from 2020-2021.

Beneficial use of biosolids as a fertiliser to improve tree growth and nutrition

10 The beneficial effects of biosolids application on tree nutrition, tree growth, wood quality, and economic return are shown in the research trial data and outlined in the TNSF Report. I summarise the conclusions I made below:

10.1 In 2015 (analysis of trees age 24 years), the average basal area (**BA**) of the trees receiving 600 kg N ha^{-1} of treated biosolids (**High Treatment)** was 23% greater than the those receiving 0 kg N ha^{-1} (**Control**), and the average BA of the trees receiving 300 kg N ha^{-1} (**Standard Treatment**) was 20% greater than the Control. The stem volumes of each application rate also varied, with the High Treatment measuring 725 m^3 ha^{-1}, and Standard Treatment measuring 697 m^3 ha^{-1}. These volumes are 25% and 20% greater than the Control respectively, which measured 582 m^3 ha^{-1}. Such outcomes indicate a substantial gain in productivity from biosolids application.

10.2 In two earlier studies (trees age 12 and 15 years) we evaluated the responses of wood properties to biosolids application at mid-rotation. This showed a 5-7% reduction in wood density and stiffness of radiata pine standing trees caused by application of biosolids at Rabbit Island. While a small reduction (5-7%) in wood quality (density and stiffness) was observed due to application of biosolids, the considerable increase in tree stem volume more than compensates for the economic value loss in reduced wood quality.

10.3 Overall, the High and Standard biosolids treatments were predicted to increase the net stumpage value of logs by 24% and 16%, the net present value by 49% and 28% respectively at harvesting, indicating a large positive impact on the forest owner's economic return.

10.4 Foliar analysis indicates that without biosolids application, the radiata pine stand suffers from N deficiency, and productivity will increase through N fertilisation via biosolids application. Overall, biosolids application significantly ($P < 0.05$) increased foliar N concentration of the Standard Treatment to a marginal level (averaging 1.4% N) and the High Treatment to a sufficiency level (averaging 1.5% N).

10.5 The predicted annual N uptake by pine trees peaked at age 6 and then decreased over the rotation period for all biosolids treatments. However, the cumulative amount of N uptake by trees at the Standard and High biosolids treatments was 751 and 786 kg ha^{-1}, respectively, increasing by 18.9% and 24.5% when compared to the Control. This indicates the biosolids application rates at Moturoa / Rabbit Island need to be adjusted according to the pine stand age.

10.6 Enhanced pine growth due to biosolids application was highly likely a result of improved soil N supply and tree N nutrition.

10.7 In consideration of the low N supply of the sandy raw soil at Moturoa / Rabbit Island, it is anticipated that the biosolids-derived N would be the main N source for pine tree growth, especially up to age 15.

Beneficial use of biosolids as a soil amendment to enhance soil fertility and quality

11 The beneficial effects of biosolids application on soil fertility and quality are shown in the research trial data and outlined in the TNSF Report. I summarise the conclusions I made below:

11.1 Repeated application of biosolids to a *P. radiata* plantation on a low-fertility, sandy soil significantly increased total C, N and P content of soil, and the plant-availability of N and P. This indicates biosolids application improved soil fertility that was beneficial to tree growth.

11.2 Repeated application of biosolids significantly increased soil microbial biomass and activities. This suggests that the slow accumulation of heavy metals from repeated applications of biosolids had no adverse effect on the growth of soil microorganisms.

11.3 Repeated application of biosolids had no significant effect on soil physical properties. This indicates that the biosolids application process had not caused any negative impact on soil physical properties.

11.4 The collembolan reproduction test with *Folsomia candida* is used as a tool to evaluate the ecotoxicological potential of organic wastes applied to soil [11-12]. Repeated application of biosolids did not have any negative ecotoxicological effects on collembolan reproduction.

Potential risks of land application of biosolids

12 Some potential risks of land application of biosolids at Moturoa/Rabbit Island are shown in the research trial data and outlined in the TNSF Report. I summarise the conclusions I made below:

12.1 Repeated applications of biosolids, especially the High Treatment (600 kg N ha^{-1}), reduced soil pH by 0.21-0.48 units on average in both surface soil (0-25 cm) and sub soil (25-50 cm). These soil pH values were however, still within the normal range of forest soils for pine growth (pH 4.5-5.0). The slight soil acidification caused by biosolids application should not create a significant adverse risk for increasing the solubility, mobility, and leaching of soil heavy metals at this stage. However, this needs further monitoring.

12.2 Repeated applications of biosolids, especially the High Treatment (600 kg N ha^{-1}), caused slow accumulation of Cu, Zn, Pb, As, Cd and As in the litter and soil. Overall concentrations of these heavy metals were well below the soil contaminant limits defined by the NZ Biosolids Guidelines 2003, however, the mobility and long-term fate of these heavy metals in the receiving environment warrant further monitoring.

12.3 The repeated application of biosolids to a radiata pine plantation on low fertility sandy soils, significantly increased soil nutrient availability, and showed a downward movement of available N and P in the soil profile, which indicates a potential risk of N and P leaching.

12.4 I note however, that the consent conditions limit the maximum biosolids application rates of 450 kg N ha^{-1}. Application of 600 kg N ha^{-1} was only adopted for research trial purposes. Therefore, the effects associated with higher application rate are not evident in the operational forestry areas.

Updates since submission of the AEE

13 I have reviewed my original TNSF Report, and provide further updates where it is necessary to address the updated 2020-2021 operational data, and provide further conclusions relevant to the same pine stands of operational areas.

14 The effects of biosolids application on soil chemical properties are updated with new soil data (2020-2021) from four selected pine stands (i.e. 1.1, 2.1, 9.1 and 9.2) in the operational areas (same pine stands as in the original report) and are summarised as follows:

Soil pH (Fig 5)

15 I conclude that soil pH patterns in both top and sub soils are sufficiently similar to those outlined in the TNSF Report (Fig 9a, TNSF Report) and therefore the 2020-2021 operational data does not change my earlier conclusions.

16 Except for some individual soil samples, the average soil pH values in both top and sub soils were all above 5.0 and meet the existing resource consent requirement that soil pH be maintained above 5.0. This discrepancy could be due to sampling errors, but needs to be confirmed in the future by adopting our recommended soil sampling protocol.

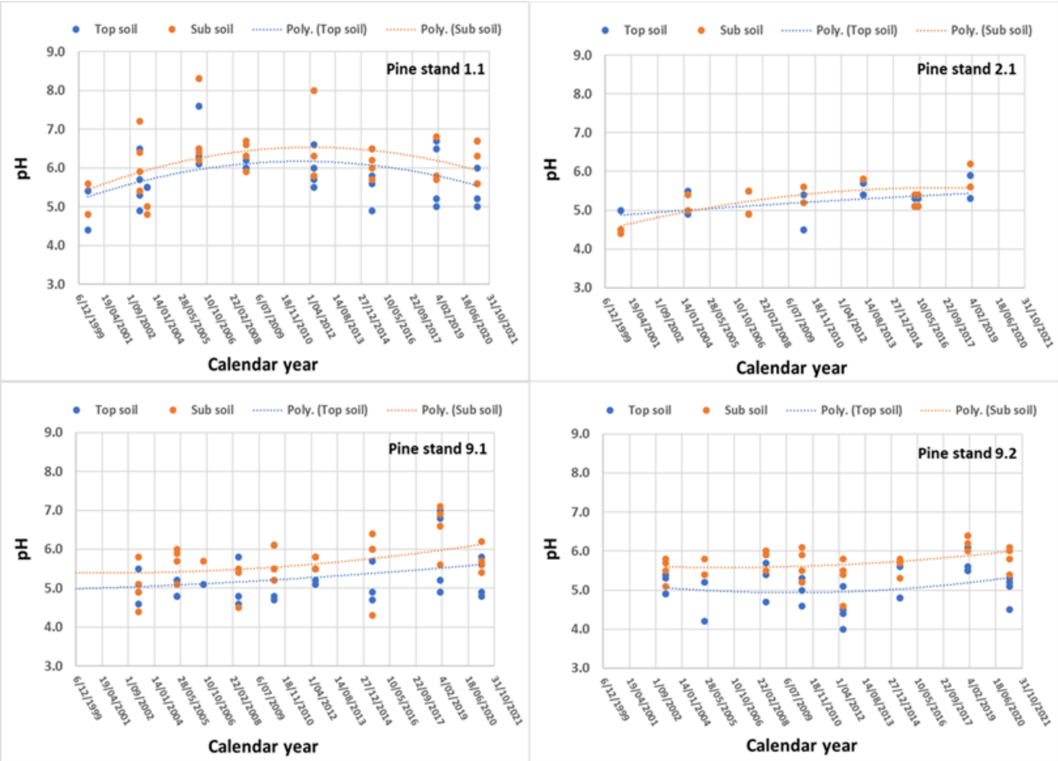

Fig 5. Changes of the average soil pH in top- and sub-soils of four selected pine stands in the operational areas over the period of 1999-2021. Poly. (Top soil) and Poly. (Sub soil) represent polynomical regression models to be fitted to the data for top and sub soils, respectively.

Soil organic matter (Fig 6)

17 I conclude that soil organic matter patterns in both top and sub soils are sufficiently similar to those outlined in the TNSF Report (Fig 9b, TNSF Report) and I therefore maintain my original conclusions.

18 The Rabbit Island soils are naturally low in organic matter and N requirements for pine tree growth should be mainly from the mineralisation of biosolids-derived organic N. This could result in a very slow accumulation of biosolids-derived organic carbon in the soil.

Soil total N (Fig 7)

19 I conclude that soil total N patterns in both top and sub soils are sufficiently similar to those outlined in the TNSF Report (Fig 9c, TNSF Report) and are not changed following my assessment of the 2020-2021 operational data. I maintain my original conclusions.

20 Soil total N contents in both top and sub soils showed a steady increase in the selected pine stands. This indicates the improvement of soil fertility in these pine stand sites by repeated applications of biosolids.

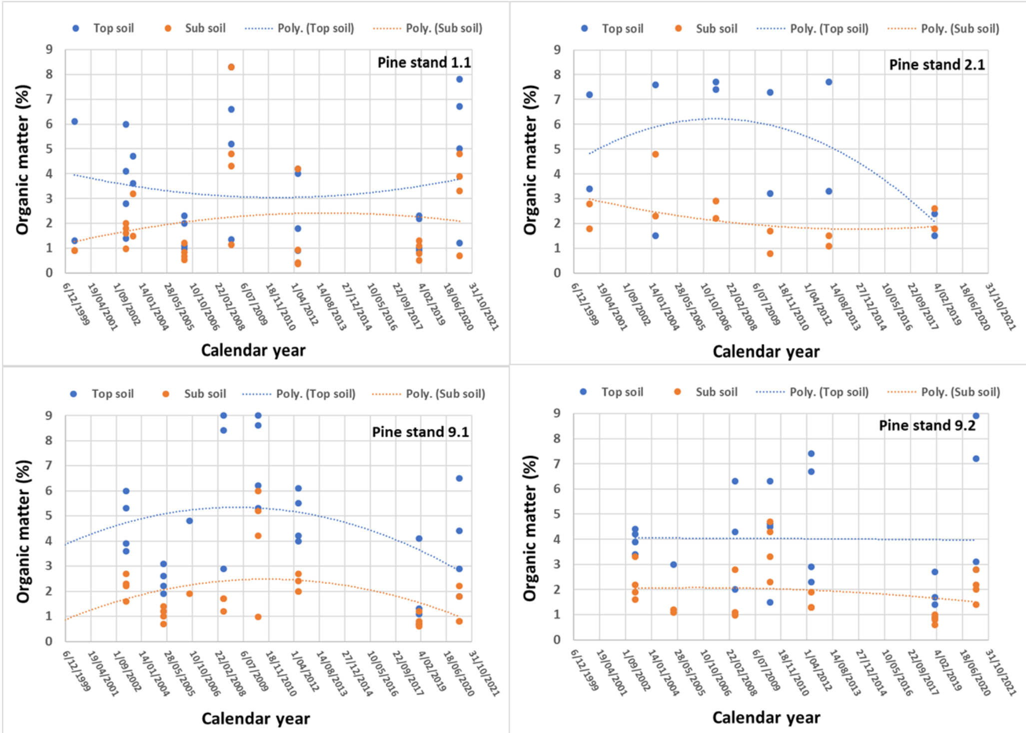

Fig 6. Changes of the average soil organic matter in top- and sub-soils of four selected pine stands in the operational areas over the period of 1999-2021. Poly. (Top soil) and Poly. (Sub soil) represent polynomical regression models to be fitted to the data for top and sub soils, respectively.

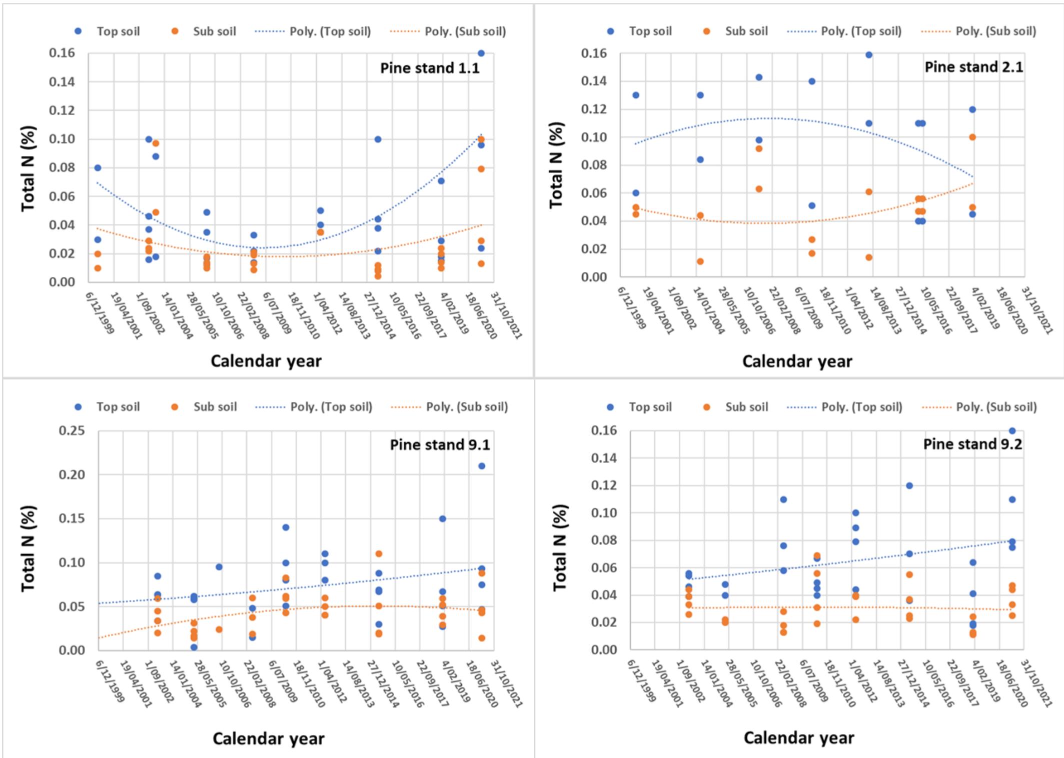

Fig 7. Changes of the average soil total N in top- and sub-soils of four selected pine stands in the operational areas over the period of 1999-2021. Poly. (Top soil) and Poly. (Sub soil) represent polynomical regression models to be fitted to the data for top and sub soils, respectively

Soil heavy metal concentrations (Table 1)

21 The effects of biosolids application on soil heavy metal concentrations are updated with new soil data (2020-2021) from eight selected pine stands within the operational areas (i.e., 1.1, 3.1, 6.1, 7.3. 9.1, 9.2, 9.3 and 10.2).

22 The cumulative effects that arise from repeated applications of biosolids on the concentrations of total heavy metals in top and sub soils of the operational areas are shown in Table 1 below. For comparison, the concentrations of soil heavy metals in the control plots of biosolids research trial are also listed in the table, together with the soil contaminant standards set by the different guidelines and Resource Consent conditions.

23 Although the Ni concentrations in both top and sub soils of some stands exceed the limit of NZ Biosolids Guidelines, it is still within the limit of Resource Consent granted (see Table 1 above).

24 Except for Ni, no other heavy metal concentrations exceeded the limits set by the NZ Biosolids Guidelines or the Resource Consent conditions during 2020-2021 in both top and sub soils (see Table 1 below).

25 The soils at Moturoa / Rabbit Island are naturally high in Ni (geogenic Ni) due to the presence of Ni-rich Dunn Mountain mineral belt within the upper estuary catchment [13]. The soils of Control plots at the biosolids research trial showed comparable Ni concentrations to soils from operational areas (Table 1). In addition, the loading of Ni from the biosolids are well under the limits, indicating a low impact of biosolids application. All those support a ubiquitous geological source influence of Ni.

Table 1. Cumulative effect of operational biosolids applications on concentrations of total heavy metals in soil during the period of 1999-2019 and 2020-2021

	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
	(mg kg^{-1})							
BRT Control [a] (0-25 cm)	2.9	0.04	43	2.6	3.6	0.03	23	21
BRT Control (25-50 cm)	3.6	0.04	42	2.7	3.4	0.05	36	21
1999-2019 data (for all pine stands and plots)								
Top soil [b] (0-20 cm)	3.66 (**35**)	0.13 (0.63)	20 (120)	3.82 (41)	3.56 (72)	0.34 (0.53)	42 (**190**)	21 (96)
Sub soil [b] (20-40 cm)	3.56 (**30**)	0.14 (0.52)	19 (100)	4.56 (65)	3.83 (35)	0.38 (0.60)	36 (**210**)	22 (150)
2020-2021 data (for 32 plots of 8 selected pine stands)								
Top soil [b] (0-20 cm)	3.01 (5.4)	0.10 (0.21)	15 (23)	7.89 (37)	4.07 (7.80)	0.05 (0.12)	26 (**72**)	27 (110)
Sub soil [b] 20-40 cm)	3.05 (5.6)	0.09 (0.16)	17 (29)	5.28 (19)	3.45 (6.80)	0.05 (0.07)	34 (**99**)	25 (91)
Soil contaminant standards								
NZ Biosolids Guidelines	20	1.0	600	100	300	1.0	60	300
NES [c]	20	3.0	>10,000 (Cr^{3+})	>10,000	210	310	/	/
Resource consent [d]	10	3.0	600	140	300	1.0	100	300

[a] *BRT Control – Biosolids research trial control. Data presented here for comparison with the operational sites*

[b] *Mean **(Maximum)** values of soil heavy metals presented for the top and sub soils*

[c] *National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health - Land-use scenario for Residential 10% Produce – a conservative limit adopted as a precautionary measure*

[d] *The resource consent limits for both top- and sub-soils, which are based on the Department of Health 1992 Guidelines for arable land*

Summary of findings

26 While I have not examined all pine stands within the operational areas, I consider that the operational data that I have assessed is representative of the balance of the remaining pine stands on which biosolids has been applied.

27 Overall, the monitoring results indicate that the repeated application of biosolids at Moturoa/Rabbit Island has not resulted in significant adverse effects on soil quality and health, and has in fact improved tree nutrition and growth of radiata pine stands. This also provides for increased economic profitability in the forest.

28 Following a review of the NZ Biosolids Guidelines, the findings in my original TNSF Report, and the results from the updated 2020-2021 data from the selected pine stands of operational areas, I make the following key findings:

28.1 The updated operational 2020-2021 data supports our findings from the research trial at Moturoa/ Rabbit Island, as detailed in the TNSF Report and briefly outlined above.

28.2 Overall, soil pH was maintained above 5, although it gradually decreased with repeated applications of biosolids over time and dropped below 5 at some sites on occasion.

28.3 Repeated applications of biosolids improved soil fertility by increasing soil total N and organic matter over time in both the top and sub soils.

28.4 Despite the slow accumulation, the concentrations of Cd, Cr, Cu, Pb, Hg and Zn remain below the soil limits defined the NZ Biosolids Guidelines 2003, and the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (MFE 2012).

28.5 While the maximum values for As and Ni were higher than the NZ biosolids guidelines soil limits on some sites occasionally, the average concentrations of As and Ni are below those limits.

28.6 The existing application rates of 300 or 450 kg N ha^{-1} every 3 years (depending on the stand age) are justified as appropriate and should be retained.

Improved soil monitoring regime is warranted to safeguard the receiving environment (e.g. soil and groundwater).

Guidance to biosolid application

29 The following documents have been developed to guide biosolids application in New Zealand:

29.1 Best Management Practices for Applying Biosolids to Forest Plantations in New Zealand (New Zealand Forest research Institute Ltd, 2010);

29.2 Guidelines for the Safe Application of Biosolids to Land in New Zealand (NZWWA, 2003); and

29.3 New Zealand Environmental Code of Practice for Plantation Forestry (NZFOA 2007).

30 The Best Management Practices for Applying Biosolids to Forest Plantations in New Zealand was developed by Scion in 2010 for backing up the biosolids research trial established in pine forests at Moturoa/ Rabbit Island and this document serves as a guide for applying biosolids to other forest plantations in New Zealand. The purpose of this document is to ensure that the learnings gained from the research trial work are available to the case-study sites nationally so that appropriate best management practice is used in all aspect of the application of biosolids to forest plantations. As Moturoa / Rabbit Island was the original case-study, the best management practices described in this document reflect in the most part the practices that are undertaken at Moturoa / Rabbit Island.

31 The Guidelines for the Safe Application of Biosolids to Land in New Zealand were produced as a joint initiative of the wastewater industry, central and local government and other key stakeholders in 2003. These guidelines supersede parts of the Department of Health's Public Health Guidelines for the Safe Use of Sewage Effluent and Sewage Sludge on Land (1992). The 1992 guidelines were used to guide the existing resource consent conditions – specifically the imposed maximum heavy metal soil concentrations. The earlier 1992 guidelines have been withdrawn by the Ministry of Health. Both the TRSF Report and this evidence, have adopted the recommended limits of the 2003 Guidelines to assess performance of the biosolids operation at Moturoa / Rabbit Island. The revised heavy metal maximum soil concentration limits recommended in the section below are taken directly from the 2003 Guidelines.

32 The aim of the New Zealand Environmental Code of Practice for Plantation Forestry is to assist forestry operators to plan, manage, and carry out commercial forest operations in a way that avoids, remedies, or mitigates adverse effects on the environment. While the code is not specifically referenced in this report it is expected that the Tasman District Council Forest Manager (PF Olsen) will operate consistently with the code.

Resource consent conditions

33 The following section of this evidence considers relevant existing consent conditions and any change recommended to these, both in light of the discussion above and to update the biosolids monitoring regime to align with industry best practice. I note that these recommendations have been included within the NRSBU recommended suite of conditions.

Application of biosolids - Existing condition 4.6

34 Based on the above discussion, we consider that maintaining the application rate provided for under the current consent is appropriate, provided ongoing monitoring is undertaken to manage potential future effects on the receiving environment.

Monitoring - Existing condition 7.1

35 Under the existing consent conditions, biosolids are primarily monitored for pathogens, and chemical properties including dry solids, organic matter, pH, total and ammoniacal nitrogen, phosphorous, potassium and heavy metals (As, Cd, Cr, Cu, Pb Hg, Ni and Zn).

36 It is important that any new consent conditions provide a pathway for the NRSBU biosolids operation to keep up to date with new monitoring requirements as these become available. An example of this would be to propose limits of PFAS in organic waste product at 0.01 mg kg-1 dry weight as contained in the Guidelines for Beneficial Use of Organic Materials on Productive Land[14]. This document is still watermarked "Draft for Public Comment" and so the NZ Biosolids Guidelines 2003 have been adopted as the current framework in assessment. However, safe limits of PFAS in biosolids have been proposed by many countries including USA, Europe,

Australia and it follows that provision is made in the new consent for any changes to the existing guideline framework to be implemented as these become available.

37 It is recommended that a Monitoring Technology Review Report be included as a condition of consent to ensure that there is an obligation on the NRSBU to maintain a current monitoring regime and to provide a pathway for the biosolids operation to respond to monitoring results over the life of a new consent.

Soils – Existing condition 7.3

38 Monitoring the build-up of contaminants in the receiving soil is an important risk management measure. The Beca Ltd Biosolids Process Alternatives Assessment confirms that the biosolids applied at Moturoa / Rabbit Island are Grade A biosolids as per the NZ Biosolids Guidelines 2003 [6], the Guidelines for Beneficial Use of Organic Materials on Productive Land [14], Class A biosolids as defined by the US EPA, and as required under the existing consent conditions.

39 After reviewing the existing soil monitoring conditions, **we recommend some amendment as follows**:

39.1 Soil from sites to which biosolids have been applied should be sampled using an unbiased pattern such as a grid or rectangle to capture the GPS location of the sample collection site.

39.2 The table included at existing condition 7.3 (b) is updated to reflect the NZ Biosolids Guidelines 2003 as per the below:

Heavy metals	**Maximum Soil Concentrations (mg/kg dry weight)**
Arsenic (As)	20
Cadmium (Cd)	1
Chromium (Cr)	600
Copper (Cu)	100
Lead (Pb)	300
Mercury (Hg)	1
Nickel (Ni)	60
Zinc (Zn)	300

It is acknowledged that the existing table 7.3 also contains maximum annual and cumulative loadings however these are only used to guide biosolids application and are not real-time indicators. Accordingly, only the maximum soil concentration limits as recommended by the Biosolids Guidelines are recommended for inclusion in the consent table.

40 Further, I consider the recommendations set out at page 4 of my TRSF report are also relevant to the biosolids application activities at Moturoa / Rabbit Island, including:

40.1 Sites that have minimum buffers or a longer season of application, and sites with a greater risk of leaching or run-off, require greater monitoring both pre- and post-application.

40.2 An independent Monitoring and Technology Review Report be imposed as a condition of consent to investigate the impacts of harvesting disturbance and pine reestablishment on provision of benefits and potential risks (e.g. fate of nutrients (N, P), heavy metals and emerging organic contaminants in the receiving environments) of biosolids land application on Moturoa / Rabbit Island. This can further reassure the sustainability of long-term biosolids application on forested land.

Comments on Officer's Report

41 The section 42A Reporting Officer, adopts the conclusions and recommendations made in the TNSF Report relating soil/ land. Furthermore, I agree with the Reporting Officers conclusion that the application of biosolids to land at Moturoa/ Rabbit Island has not resulted in a significant adverse effect, and that the proposed regular monitoring will protect the soil and land throughout the proposed 35-year term of this consent.

Comments on Submissions where relevant to my evidence

42 In their submission on the Application, Te Runanga o Ngāi Rarua have requested NRSBU to assess alternative approaches to treating biosolids before application to land on Moturoa / Rabbit Island. I make the following comments where relevant to my area of expertise:

43 The use of biosolids as a fertiliser and soil amendment for the improvement of low fertility soils and reclamation of degraded land is the most common biosolids management option in many parts of the world. In New Zealand, the application of biosolids to forestry is preferred over the application of such to agricultural land, because it can reduce the risk of contaminants entering the human food chain, and also increases tree growth and subsequent economic returns (as explained in the body of my evidence) [3-5,8-9]. Our early Life Cycle Assessment at CIBR (Centre for Integrated Biowastes Research) also supported the direct application of biosolids to forest land with less carbon footprint than application of composted or vermicomposted biosolids.

Jianming Xue

11 May 2022

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